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The Effect of a Second Magnetic Layer on Hard Bubbles

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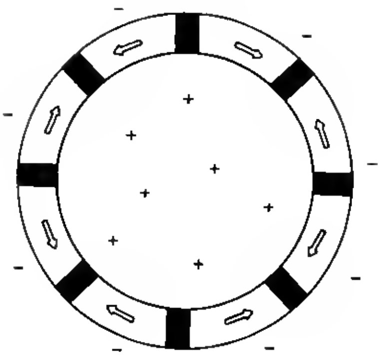
A new class of magnetic bubbles designated as hard (and intermediate) bubbles has been found to be a common feature in many bubble garnet films.[1] These hard bubbles have been very disruptive to the operation of bubble circuits since they not only have a much lower mobility than normal bubbles, but also tend to move at an angle rather than parallel to the direction of the driving field gradient. Fortunately, it has recently been found that the presence of a second magnetic layer apparently eliminates these hard bubbles.[2,3] This second layer can either be a growth layer with a sufficiently small moment so that its magnetization under a bias field is always oppositely directed to the magnetization within the bubble,[2] or it can be a layer with magnetization perpendicular to the bubble magnetization. This latter layer might be produced by ion implantation to the point where a stress-induced uniaxial anisotropy in the plane of the film overcomes the previously existing anisotropy.[3] We propose in this B.S.T.J. Brief that the apparent elimination of these hard bubbles is due to the presence of the domain wall between the bubble and this second layer.

The static and dynamic properties of these hard bubbles have recently been accounted for by a model[4,5] which assumes that the domain wall which forms the perimeter of the bubble is segmented into Bloch segments of opposing polarity separated from one another by Néel segments as shown in Figs. 1a and b. As long as the spin rotation of Fig. 1b is always clockwise or counterclockwise as one proceeds around the bubble perimeter, then such a segmented configuration remains



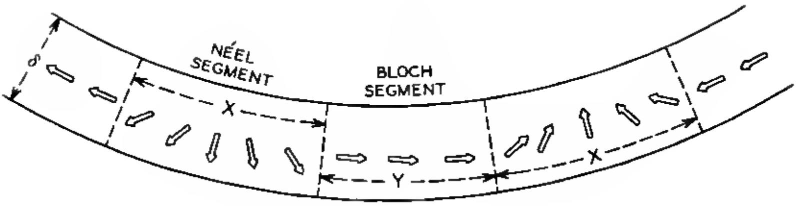


Fig. 1—(a) Pictorial representation of a bubble with a perimeter wall composed of Bloch wall segments separated by Néel segments (dark regions). (b) Pictorial representation of the actual spins through 3 Bloch segments separated by 2 Néel segments. Note that in going from left to right the spin rotation is counterclockwise.

locked in, that is, it cannot unwind through small perturbations. Thus a bubble with $2n$ Néel segments will remain with $2n$ Néel segments as long as there is no second magnetic layer. When a second magnetic layer is present, however, only a $2n = 2$ bubble is stable. We shall illustrate this statement by considering what happens when a $2n \neq 2$ bubble is shifted from a region having only one magnetic layer to a region with two magnetic layers. In Fig. 2 we show a side view of a bubble within a two-layer region where the second layer has its magnetization antiparallel to that within the bubble.

Let us now consider the case of a hard bubble with 4 Néel segments ($2n = 4$) as shown in Fig. 3a, where there is no second magnetic layer present. In Fig. 3b we have shifted this bubble into a region having a second magnetic layer until about 2/3 of the bubble is in contact with this layer. Here we have assumed an oppositely-directed second layer with a 180-degree domain wall between the bubble and this layer. We shall refer to this wall as the planar wall and the wall around the

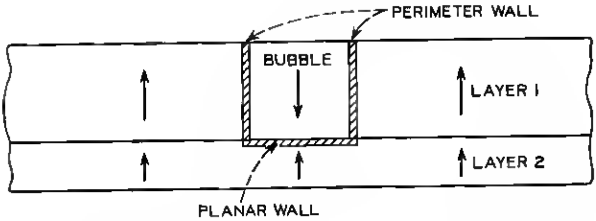


Fig. 2—A side view of a bubble in a region with two magnetic layers showing the perimeter and planar domain walls.

buhhle as the perimeter wall. The white arrows represent the spins in the planar wall, while the dark arrows represent the spins in the perimeter wall. We note that tbe ferromagnetic coupling of tbe spins in the planar wall tends to attempt a clockwise rotation on the spins in the left half of the perimeter wall. This interaction between the planar and perimeter spins can be thought of as a perturhing molecular field on spin (1) being oppositely directed to its spin direction. As the huhhle is pushed furtber onto this second layer, the perturbing field on the spins on the left-half side of the perimeter wall hecomes even stronger as shown in Fig. 3c. Finally when this perturhing field hecomes large enough, the perimeter spins closest to the planar wall will flip to the directions sbown in Fig. 3d. Tbis flipping of the perimeter spins closest to the planar wall results in a similar flipping of the perimeter spins further up along tbe wall heigbt until all the spins in tbe perimeter wall will be parallel to those in the planar wall as shown in Fig. 3d.

Thus this $2n = 4$ huhhle has converted to a $2n = 2$ buhhle when the planar wall is present. It can be shown in a similar manner tbat a hubble of any given $2n$, with perimeter spins wound either clockwise or counter-clockwise, will always convert to a huhhle with this particular $2n = 2$ configuration when placed in contact with a planar wall. This is true not only of 180-degree planar walls but also of the 90-degree planar walls between the hubble and an ion-implanted layer.

If we now consider a normal bubble ($2n = 0$) being placed in contact with a second magnetic layer, we can show in a similar manner that the effect of the planar spins is to convert tbis normal bubhle to a $2n = 2$ huhhle as well. This $2n = 2$ buhble is the only stable bubble when two layers are present, even if the buhhle originates within a two-layer region.

The presence of a second magnetic layer, magnetized eitber anti-parallel or perpendicular to the magnetization within the bubhle, will result in only one type of bubble being present. This bubble is a weakly

intermediate bubble with 2 Néel segments ($2n = 2$) in the perimeter wall arranged so that the perimeter spins are parallel to those in the planar wall between the two magnetic layers. Thus the perimeter spins are essentially parallel to each other. These $2n = 2$ bubbles will have both static and dynamic properties similar to tbose of the normal bubbles since thare are only two Néel segments present.

Finally, the spin-flipping that presumably occurs as one pushes a bubble with $2n \neq 2$ onto a magnetic layer should result in an energy

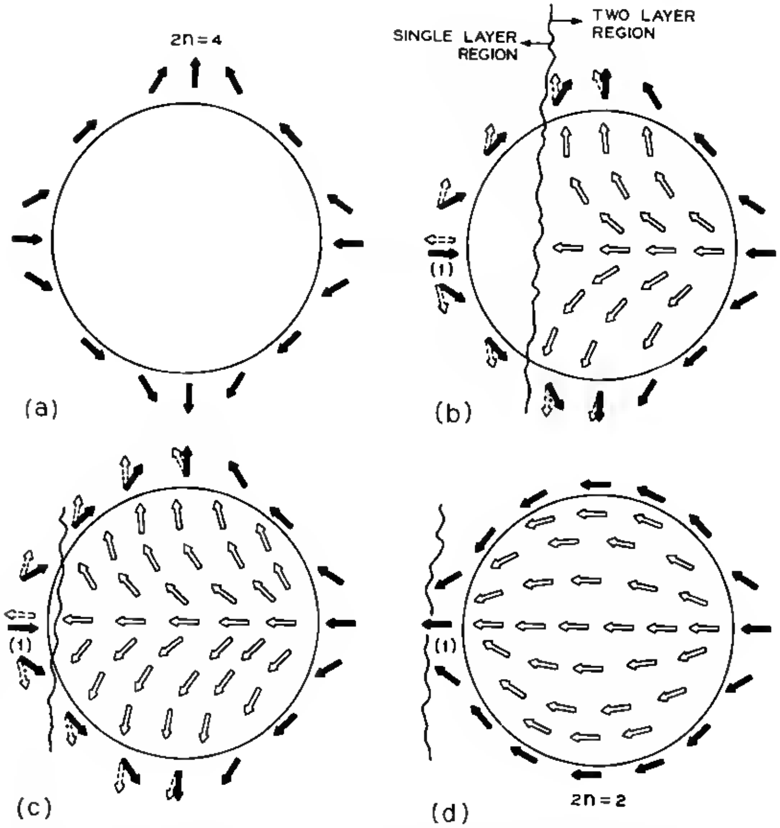


Fig. 3—(a) A $2n = 4$ bubble not in contact with the second magnetic layer. (b) The bubble in contact over 2/3 of its area with a planar wall due to the second magnetic layer. The white arrows represent planar wall spins and the dark arrows perimeter wall spins. The dashed lines represent the molecular fields due to interaction with the planar wall. (c) The bubble in contact over 90 percent of its area with this planar wall. (d) The bubble completely onto tbe second magnetic layer. The spin flips have occurred and the bubble is now a $2n = 2$ bubble.

barrier which acts as a force preventing the bubble from fully entering the region containing this magnetic layer. The magnitude of this barrier should increase with increasing n, that is, the harder the bubble, the harder it should be to push this bubble fully onto the layer. Also the barrier magnitude should be temperature dependent, decreasing strongly as one approaches the Curie temperature. Experiments to test the above statements can be done by exposing a region of a bubble film to ion implantation and then noting the force or energy needed to move various bubbles onto this region.

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